

## THE EFFECT OF INFLATION ON THE TOTAL PREVENTIVE MAINTENANCE COST OF A SCHEDULING MODEL

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### ABSTRACT

The concept of inflation in the engineering economics is not a new star, but new in its applied form to maintenance scheduling. While it has diverse applications in manufacturing such as inventory control and engineering design, the literature, concerning inflation on maintenance scheduling is conspicuously absent. Certainly, inflation is an important factor in models that deal with cost issues. In this work, an investigation into the effects of inflation on a maintenance scheduling model, originated by Charles-Owaba [6], is made. In particular, the Vogel Approximation Method (VAM) which is considered as the most suited method for the model is used for analysis. A deliberate attempt is made to analyze the differences in the cost behaviour between a normal situation and a situation where cost is inflated. With this, the original data proposed by the model originator is utilized to demonstrate these differences.

**KEYWORDS** maintenance scheduling, analysis, gantt chart, optimality, computation

### 1. INTRODUCTION

Inflation is a worldwide phenomenon that has received increased attention and research activities in the last few years [5, 11, 12, 16, 20, 21, and 22]. The magnitude of attention given to this important subject has reached a heightened stage with an increased interest to study the concept of inflation, both at the local and international levels [14, 19, 23, 24, 25, 27 and 28]. Recently, a number of documentation has been made at country levels, in Malaysia [8], four African countries [10], Australia [13] and Latin America [15]. However, more relevant to manufacturing systems is the concept of inflation applied to maintenance scheduling situations.

In view of the cost components of some maintenance scheduling models such models are amenable to an inflation treatment [18]. The justification for this lie in the periodic changes of the cost elements that such models contain. Take a maintenance scheduling situation where spare parts are used for car repairs. The cost of purchasing the same spare parts in period  $i$ , may defer from what obtains in period  $(i + 1)$  or period  $(i + 2)$ , where  $i$  is the starting year, and 1 and 2 are the successive years. This argument for changes in prices of items over time was presented by Oke [17].

Since then no documentation seems to have been made to study the effects of inflation for the maintenance situation. This is a challenge that the current work seeks to address. With this work, a number of opportunities for investigation into the inflation

based modeling problem are created. Such opportunities may be the empirical test of the model under a wide range of circumstances.

## 2. LITERATURE REVIEW

In this section, we discuss the literature review on the subject of inflation to establish that no previous work on this current problem has been attempted [7,9,15].

Cheng and Tan [8] discuss on maintaining a low and stable inflation rate that has become one of the challenges in the macroeconomic management of most countries. It focuses on Malaysia as a unique example in terms of inflation of which the Malaysian economy was described as experiencing episodes of high (1973-1974, 1980-1981) and low (1985-1987) regimes of inflation, and was able to contain low and stable inflation during the high economic growth period of 1988-1996. The objective of the study is to identify important factors that contribute significantly to inflation in Malaysia.

The study also aimed at examining the possible existence of international and intra-ASEAN inflation transmission to Malaysia. The analysis is carried out based on the time-series approach of multivariate co-integration, vector error-correction modelling, impulse response functions and variance decompositions. The empirical results of this study show that external factors such as exchange rate and the rest of ASEAN's inflation are relatively more important than domestic factors in explaining Malaysian inflation. This contribution is helpful with an insight on the possibility of developing an integrated model involving exchange rate situations, the purchasing power of users and the level of demand into the general maintenance scheduling cost.

In another study, Schofield [19] suggests that recent attempts to measure the inflation-hedging characteristics of commercial property use an inappropriate methodology. As a result, the conclusions of much of this body of work are of dubious value. Having an income and capital repayment linked to inflation, index-linked gilts appear to be a good hedge against inflation. It applies traditional regression-based inflation hedging tests to UK index-linked gilts. The tests suggest that index-linked gilts are not hedges against inflation. There is an anomaly. The anomaly is resolved through explicitly defining a hedge against inflation and, given the definition, building a model to test if index-linked gilts are hedges against inflation. It concludes that index-linked gilts are hedges against inflation and that the regression-based methodology is an inappropriate one.

Given this, the finding uses the procedure to assess the inflation-hedging capacity of a single standard UK commercial property. It is found that property is around 20 percent prone (80 percent inflation proof). Finally, the assumption of single property is relaxed to consider the characteristics of the portfolio of investment. This does not significantly change the results.

Al-Khazali [2] proposes that vector-auto-regression (VAR), integration, and co-integration models are used to investigate the causal relations, dynamic interaction, and a common trend between interest rates and inflation in nine countries in the Pacific-Basin. The paper finds that for all countries, short- and long-term interest

rates, and the spread between the long-term interest rates and inflation are non-stationary (I) processes. The nominal interest rates and inflation are not co-integrated. In addition, this study is unable to find a unidirectional causality between inflation and interest rates, when the VAR model is used. It also fails to find a consistent positive response, either of inflation, to shocks in interest rates or of interest rates to shocks in inflation in most of the countries studied. The VAR model results are consistent with the integration test results; that is, nominal interest rates are poor predictors of future inflation in the Pacific-Basin countries.

In another work, Tarbert [25] proposes that historically, investments in commercial property have been perceived as providing a hedge against inflation. A complete hedge against inflation is formally defined as an asset where the nominal returns vary in a positive one-for-one way with inflation. The belief that commercial property is an inflation hedge has persisted, notwithstanding the fact that many empirical tests have proven inconclusive. Use of the traditional methodology in this paper also produces poor results, although the hypothesis that commercial property is a hedge cannot be rejected. Explores the reasons for these poor results, and introduces a method of testing for a long-run hedging relationship, based on co-integration. Co-integration techniques reject the hypothesis that commercial property is a consistent long-run hedge against inflation.

Abul, et al. [21] conducts both the cointegration test of the monetary theory of inflation and the Granger-causality test between the variables in the system, and also develops univariate and multivariate time series models to forecast inflation rates. Quarterly time series data for Pakistan, from 1972-2 to 1993-4 is used for empirical investigation. Results suggest no cointegrating or long run relationship between the variables in the monetary model. Observes that there is some evidence of Granger-causality running from inflation to growth. Comparison of out-of-sample quarterly forecasts for the 1988-1 to 1993-4 period are made for univariate and vector ARMA models of inflation. States that the forecasting accuracy of the multivariate ARMA model is not statistically different from that of the univariate ARMA model.

Spithoven [23] describes the fear of inflation that has frustrated European employment policies since the early 1970s. It states that the concurrence of much unemployment with inflation did not elicit new ideas and that governments postulated that excessive spending, social security payment in particular, is the main cause of both: this legitimised severe restrictive monetary and fiscal policies but expected results failed to appear. Finds that inflation did indeed abate but the increase in unemployment did not. This suggests that because the services required for improving human capital are a prerequisite for economic progress, it follows that the state has to guarantee at least minimum conditions for ready access to services.

For a calculating government, this is difficult to implement. That is why the dominating calculating principle in politics (a sort of monetarist bookkeeping attitude) undermines the economic performance of a country and threatens democracy. Yet the monetarist economic framework persists. Moreover, indicates the Maastricht treaty actually establishes a legal and economic framework by which price stability takes precedence over growth, reduction of unemployment and social welfare considerations. Feels that a re-examination of the true causes of inflation and unemployment has become imperative.

Makin [13] examines the effect of domestic inflation on recorded measures of the current account of the balance of payments. When domestic inflation is relatively high, it distorts conventionally measured current account deficits. This is because part of the recorded servicing payments on external liabilities is actually capital repayments and hence should be shown on the capital account. The work presents estimates of Australia's inflation-adjusted current account deficit as an example of the methodology outlined. These estimates suggest that in practice, Australia's inflation-adjusted account deficit throughout the 1980s, expressed as a proportion of GDP, be under half the value of the nominal measure. When nominal measures of external deficits differ substantially from inflation-adjusted outcomes, they can give misleading signals to policy makers.

The empirical results suggest that a bivariate relationship between inflation and productivity is spurious, as the unit root pre-tests that account for oil shock episode show that inflation and productivity are integrated of a different order. When we control for fluctuations of overall economic activity and monetary policy on the bivariate relationship between price level and productivity, the evidence suggests that Granger-causation must exist in at least one direction. VECM estimation showed that productivity growth and inflation are econometrically endogenous variable and this suggests that bi-directional causality from inflation to productivity growth and vice versa exists.

In another study, Mallik and Anis [14] examines the relationship between inflation and real income in Australia, Canada, Finland, New Zealand, Spain, Sweden and the UK which have adopted a "formal" policy of low or zero inflation target. Using cointegration analysis and a vector error correction model (VECM), it is found that the long-run relationship between inflation and real income is positive in most cases. We further find that contrary to the belief of new-classical economics, government expenditure too is positively related to real income in the long run.

Hamelink and Hoesli [11] test the inflation-hedging effectiveness of Swiss real estate. Four proxies for expected inflation are used, two of them being based on autoregressive conditional heteroscedasticity models (ARCH-M and QTARCH). The series used to proxy for real estate returns is a transactions-based series adjusted for quality of the buildings by means of a hedonic model. Swiss stocks, bonds, real estate and real estate mutual funds are usually positively related to expected inflation and negatively related to unexpected inflation. Many of these coefficients, however, do not exhibit statistical significance.

Hoesli [12] tests the inflation-hedging ability of Swiss real estate over the 1943-1991 period and, for comparison purposes, that of stocks. When the inflation rate is broken down into its expected and unexpected components, all coefficients are negative for stocks whereas some coefficients are positive for real estate. This is particularly true for unexpected inflation. These results are interesting in that the proxy used for real estate (i.e. data pertaining to real estate mutual funds) should be a much better indicator of changes in the underlying real estate than indices which have been used so far. Moreover, the data exists for a very long time period, which makes it possible to test the long-term ability of real estate to hedge against changes in the purchasing power.

In another paper, Stevenson [24], examines the literature concerning the British regional housing markets and proposes that it has been relatively limited, especially in comparison to the research undertaken with regard to the commercial market. The paper aims to redress the balance primarily in two areas. First, the performance of regional housing markets over the period 1983 to 1995 is assessed and compared to comparable returns from the commercial sector and the UK equity and bond markets. The second area of concern is the inflation hedging ability of these markets. While a large number of studies have examined the UK commercial sector, the residential market has been largely ignored.

Smyth [22] noted that the annual rate of growth of the average salaries of faculty at universities and colleges has fluctuated considerably from year to year. Analyses annual academic year data on salaries from 1971-72 to 1991-92. Results were presented for continuing faculty (Faculty on staff in both the reporting year and previous year), and for total faculty, in both cases disaggregated by rank. Two macroeconomic variables, the expected rate of inflation and whether or not the economy is in recession, provide a good explanation of how large the percentage increase in salaries will be for the forthcoming academic year, and in conjunction with the actual rate of inflation, the behaviour of real salaries of academics. The estimates provide a gloomy outlook for real academic salaries

Boott [4] considers the implications of the return to floating exchange rates for future inflation. Analysis changes in investment yields in conventional and index-linked bond markets in order to estimate changes in the inflation forecasts of investors and real yields required by investors. The author applies forecasts to commercial property markets to ascertain possible long-run effects on the property market of movements in other markets. They conclude that information from other markets can be used in the analysis of property investment.

In another paper, Wirth [28] proposes that a recent British study has shown that stock control based on reorder level/cycle is the most commonly used operational research technique in manufacturing industry. However, a review of literature on the effect of inflation on reorder levels reveals that some authors have quoted inconsistent results. The literature is summarized and analysis that corrects some previous work and extends other results is provided.

Tutton [27] describes the key elements of emergency inflation system design and highlights the considerations that have to be determined during the progress of the project. In addition, identifies and discusses some of the typical problems that have to be resolved, primarily because most of the older aircraft in service were designed without consideration for the installation of emergency inflation equipment.

Backham et al. [3] presents results of an investigation of the inflation-hedging characteristics of UK property. Evaluates the various methods of decomposing inflation into its “expected” and “unexpected” components, using new time series data on inflation expectations produced by a questionnaire survey of informed market participants. Utilizes the power and suitability of causality and co-integration analysis to examine the relationship between inflation and property returns. Analyzes the

sensitivity returns. Concludes that property is best seen as offering hedging characteristics that are only revealed in the long run.

In another study, Aiken [1] proposes that forecasting inflation is a major concern for economists and businessmen. Most researchers have relied upon statistical techniques with their stringent data assumptions and low accuracy rates to predict changes in inflation, but only a few have investigated how neural networks can improve forecasts. Here, we show the results of consumer price index (CPI) forecasts from artificial neural network using leading economic indicator data in the USA. Results show that the neural network predicts the level of the CPI with a high degree of accuracy.

Marinakis [15] proposes that during the 1980s, Latin America's inflation problem worsened, and successive stabilization programmes failed in many countries. This led to an increasing concern about the degree of rigidity imposed on the economy by different labour market structures built up over many decades. Wage-indexation, in particular, was often blamed for the failure of stabilization and adjustment programmes.

It examines the different components of an indexing system and assesses the degree of flexibility that the system implemented in some countries brought to the labour market. While a particular indexing system may have the effect of reducing wage flexibility in certain periods, the analysis of data at the macro level shows that in the long-run term wage indexation has not been insurmountable obstacle. It stresses that wage determination is just one of the key processes with a substantial influence on inflation. In the case of high inflationary countries, the existence of various key prices draw attention to the need for coordination in the adjustment of different prices during the application of a stabilization programme.

In a paper, Tegene [26] inferred that the monetarist model of inflation is tested with quarterly data over the period 1960-1983 from six African countries: Egypt, Ghana, Morocco, Nigeria, Sudan, and Tunisia. The role of foreign factors in the inflationary process is examined in the model, the lag length is determined, the issue of causality is addressed and structural stability is tested. The empirical results are, in general, consistent with the monetarist explanation of inflation.

### 3. ANALYTICAL FRAMEWORK

Given that,

$$C_{ij} = \begin{cases} [a_i + d_i (j-k_1)] (1+\alpha)^{+j}, & \text{if } (j-k) \geq 0 \\ \infty, & \text{otherwise (infeasible alternative)} \end{cases}$$

where,  $a_i$  and  $d_i$  are cost parameters,  $j$  = period,  $k_i$  = arrival period and  $\alpha$  = inflation factor.

Assuming a situation where the inflation factor increases at a steady rate of 0.05%,

Vehicle (i)	Arrival period (k <sub>i</sub> )	Mtce duration (B <sub>i</sub> )	a <sub>i</sub> x 10 <sup>2</sup> (N)	d <sub>i</sub> x 10 <sup>2</sup> (N)	Inflation rate (5%)
1	6	5	15.23	3.4	0.05
2	4	3	22.00	7.8	0.05
3	2	3	18.75	4.5	0.05
4	1	4	27.15	6.3	0.05
5	7	2	9.00	2.20	0.05
6	1	5	13.00	5.6	0.05
7	5	2	31.00	9.6	0.05
8	3	3	19.50	5.0	0.05
9	8	3	26.10	8.7	0.05
10	4	3	20.40	7.3	0.05
11	2	3	23.12	7.9	0.05
12	1	4	15.70	4.1	0.05

### 3.1 The effect of inflation on cost using Vogel's approximation method

From the general cost equation,  $C_{ij} = \begin{cases} a_i + d_i (j-k), & \text{if } (j-k_1) = 0 \\ \infty, & \text{otherwise (infeasible alternative)} \end{cases}$

An inflation factor was developed. Instituted into the equation in order to determine the effect of cost.

Let the inflation factor be  $(1 + \alpha)^j$ , where  $\alpha$  = inflation rate, which in this case is 5%,  $j$  = period. A final cost table was generated and Vogel approximation method was applied to determine the optimal preventive maintenance cost, idle period and vehicle operation period.

From the results obtained for the optimal preventive maintenance cost, it can be inferred that the effect of inflation increases the cost to about 100% of its initial value. It should be noted that any little increase in inflation would result in an increase in maintenance cost.

In a growing economy, the rate of inflation may increase exponentially due to some factors beyond the scope of this write up. In this case, the optimal maintenance cost will increase adversely until an infeasible alternative is taken. Such alternatives could be planned usage and resale of vehicles after the operating period of the vehicle and re-procurement of new vehicles. It should be noted that preventive maintenance action taken on a vehicle is as good as bringing the vehicle back to its new state. Also subsidizing the cost of vehicle spare parts by government can help reduce the effect of inflation on preventive maintenance.

Factors considered before preventive maintenance action is taken include:

- Amount of mileage spent by a vehicle.
- Conditions of the environment (environmental stresses)
- Type of tasks the vehicle is used for.
- Size of the vehicle
- Accidental occurrence

- The vehicle is as good as new after repair
- The average downtime per unit time shortly after P<sub>m</sub> will be less than the average downtime per unit time had no planned maintenance been carried out.

Other factors that affect system performance include the training, competence and motivation of the personal performance (P<sub>m</sub>) and management attitude.

#### 4. CONCLUSIONS AND FUTURE DIRECTIONS

Research on maintenance scheduling has steadily increased over the past several decades. In today's very competitive operations, production and marketing greater demands are placed on companies to improve their products and processes in terms of both performance and cost. This involves considerable investment to optimize existing systems and innovate new concepts. Maintenance scheduling research has evolved as a successful effort in achieving this objective. While a number of innovative and up-to-date approaches exist in the literature, some gaps are created necessitating the development of robust practical and theoretically based frameworks for complex systems.

The case of multiple facilities maintainable in multiple periods is of paramount importance and has been addressed in this work. In particular, we extend the novel result by Charles-Owaba [6] by incorporating inflationary factors, which is key to the model in view of its cost dimensions. Some computational experimentation on the new model is tested. This work is perhaps the first to advance the extension of the OGC model in terms of inflation. The work presents a wealth of research opportunities and has at least the modest potential to evaluate the maintenance scheduling theory into the ranks of major theories of maintenance.

In this model, an inflationary factor was considered from the inflation literature as  $(1 + \alpha)$  and when considered over a certain period, it becomes  $(1 + \alpha)^j$  where  $j$  is the maintenance period which could be in seconds, minutes, hours, days, weeks or months. This inflationary factor was instituted into the optimal maintenance model and illustrated using the mass transit vehicle example. During operations research, the effect of inflation was noticed to increase by  $(1 + \alpha)$ , where  $\alpha$  = inflationary factor and when considered over a period, it is expressed as  $(1 + \alpha)^j$ , this now opens avenues for more research work into the exponential, trigonometric and other possible mathematical outcomes of the inflationary effect.

Also, the rate of inflation will determine how stable and applicable the optimal preventive maintenance model would be. A more realistic case is the outcome of the model in developing nations. From operations research, it can be construed that the optimal preventive maintenance model, a careful analysis of the effect of inflation is necessary.

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